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Electroretinography in Dogs and Cats. Part II. Technique, Interpretation, and Indications

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Abstract
Electroretinography, a technique that objectively assesses the function of the retina, is used to evaluate the progression of retinal disorders. Part I of this two-part presentation discussed the morphologic and physiologic characteristics of the retina. The information presented in Part II can help practitioners determine when an electroretinogram (ERG) is recommended. In addition to the standard flash ERG, visual evoked potentials (VEPs) are useful for evaluating disorders that lead to blindness.

The most common indications for electroretinography are presurgical evaluation of patients with cataracts, characterization of disorders that cause blindness, and identification of the extent of retinal damage caused by glaucoma. A flash ERG can only show changes that occur to the retina in advanced stages of glaucoma; whereas a pattern ERG (PERG) can record early, selective damage to ganglion cells in the retina.

Disciplines
Eye Diseases | Medicine and Health Sciences | Ophthalmology | Veterinary Medicine

Comments
Dr. Komáromy was affiliated with the University of Pennsylvania from 2003-2012.

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Electroretinography in Dogs and Cats. Part II. Technique, Interpretation, and Indications

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FOCAL POINT

- The most common indications for electroretinography are presurgical evaluation of patients with cataracts and diagnosis and staging of disorders that result in blindness.

KEY FACTS

- Because electroretinographic values vary according to the specific machine being used, diagnostic protocols, and the breed being tested, the amplitudes and implicit times obtained from different laboratories can be difficult to compare, p. 355.
- The electroretinogram records the difference between the potential of the corneal electrode and that of the nearby reference electrode, p. 356.
- Repetitive stimuli of varying frequency, degree of adaptation to a light or dark environment, and variation in the intensity of the stimulus can be used to evaluate the function of rods and cones separately, p. 356.
- Visual evoked potentials reflect central visual function, p. 359.

Electroretinography, a technique that objectively assesses the function of the retina, is used to evaluate the progression of retinal disorders. Part I of this two-part presentation discussed the morphologic and physiologic characteristics of the retina. The information presented in Part II can help practitioners determine when an electroretinogram (ERG) is recommended. In addition to the standard flash ERG, visual evoked potentials (VEPs) are useful for evaluating disorders that lead to blindness.

The most common indications for electroretinography are presurgical evaluation of patients with cataracts, characterization of disorders that cause blindness, and identification of the extent of retinal damage caused by glaucoma. A flash ERG can only show changes that occur to the retina in advanced stages of glaucoma; whereas a pattern ERG (PERG) can record early, selective damage to ganglion cells in the retina.

TECHNIQUE

Flash Electroretinogram

The two primary components of an electroretinographic unit are the stimulating and the recording systems. The stimulating system usually consists of a blue-white xenon flashlight unit that stimulates the retina.[1] Because comparison of ERGs from different animals or of ERGs performed at different times depends on consistent measurements, the light source needs to be calibrated (i.e., the intensity of the light must be measured and readjusted so that the intensity is consistent). Because different electrotetinographic units are used at various laboratories, direct comparison of measured values for a given patient requires extreme care.

A corneal contact lens electrode is often used to record ERGs. An ERG reflects the difference between the potential of the active corneal electrode and that of a nearby reference electrode, which is usually placed at the lateral canthus (Figure 1). Electric interference (commonly referred to as noise) is minimized by a ground electrode and differential amplification and filtration of the response (typical bandpass, 1 to 300 Hz).[1] A differential amplifier measures the difference between the electric potentials of the active electrode input and the reference electrode input. If these electrodes are spaced reasonably close to each other and have similar characteristics, electric interference can affect both inputs with almost the same amplitude. The interference is therefore considered common. Because the differential amplifier only responds to the difference between signals, most of this common interference is not amplified but eliminated (so-called common mode rejection). Because the active electrode is placed close to the retina and the reference electrode is placed in an electrically silent area, the signal from the retina is amplified because the difference between the active and reference inputs is large.[2] By averaging a number of individual electroretinographic recordings, the electric noise interfering with visualization and interpretation of the ERG waveforms can be accommodated, and signals invisible or poorly appreciable in single responses can be revealed. The use of signal averaging should not, however, replace careful control of stimulating and recording conditions.[1] In addition, various software packages that record and analyze ERGs are available. The cost of these packages, however, generally limits their use to ophthalmology specialty clinics.

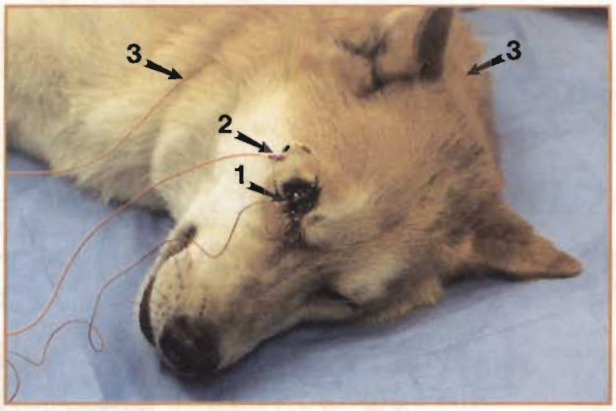

Figure 1A

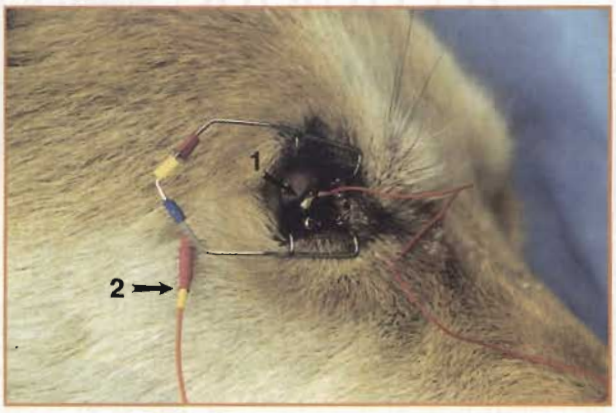

Figure 1B

Figure 1—(**A** and **B**) Placement of electrodes for electroretinographic recordings. An electroretinogram records the difference in potential between the active corneal contact lens electrode (*1*), which contains a thin gold film, and the intradermal reference electrode (*2*), which is positioned about 1 cm caudal to the lateral canthus. The ground electrode has been placed over the external occipital protuberance (*3*). A lid speculum is used to spread the eyelids.

Repetitive stimuli or flickers of varying frequency, adaptation to light or dark, and variation in the intensity of the stimulus can be used to evaluate rods and cones separately (see Part I, Table I). The functioning of rods is recorded at low stimulus intensities (below the cone threshold) and at 20 Hz or slower in flickering frequency. Cones respond at higher intensities and faster flicker rates (30 Hz and above). The flicker-fusion response curve can be an important tool to evaluate retinal degenerations (Figure 2). For early diagnosis of inherited degenerations of rods and cones (e.g., progressive retinal atrophy [PRA]), longer adaptation times to light can also be used to isolate cone responses and longer adaptation times to dark to isolate rod responses.

Table I shows the protocol currently used at the University of Florida Veterinary Medical Teaching Hospital (UF-VMTH) for most diagnostic ERGs, which were performed primarily on candidates for cataract surgery. First, the pupils are dilated with a mydriatic (usually 1% tropicamide). Dogs are sedated intravenously with acepromazine maleate (0.02 mg/kg) and butorphanol tartrate (0.2 mg/kg) and placed in lateral or sternal recumbency. The ground electrode is positioned over the external occipital protuberance and the reference electrode approximately 1 cm caudal to the lateral canthus (Figure 1). Both are fine-needle electrodes. After a topical anesthetic (0.5% tetracaine hydrochloride ophthalmic solution) is applied, the eyelids are spread with a lid speculum so that the entire cornea is exposed. A corneal contact lens electrode is then placed on the cornea using a conductive 2.5% hydroxypropyl methylcellulose wetting solution with ions (Figure 1). The light source is installed approximately 3 to 4 cm from the surface of the cornea for equal illumination of the entire retina. Photopic testing (light adapted) is done with the room lights on and the animal facing a white, illuminated wall. Scotopic test-

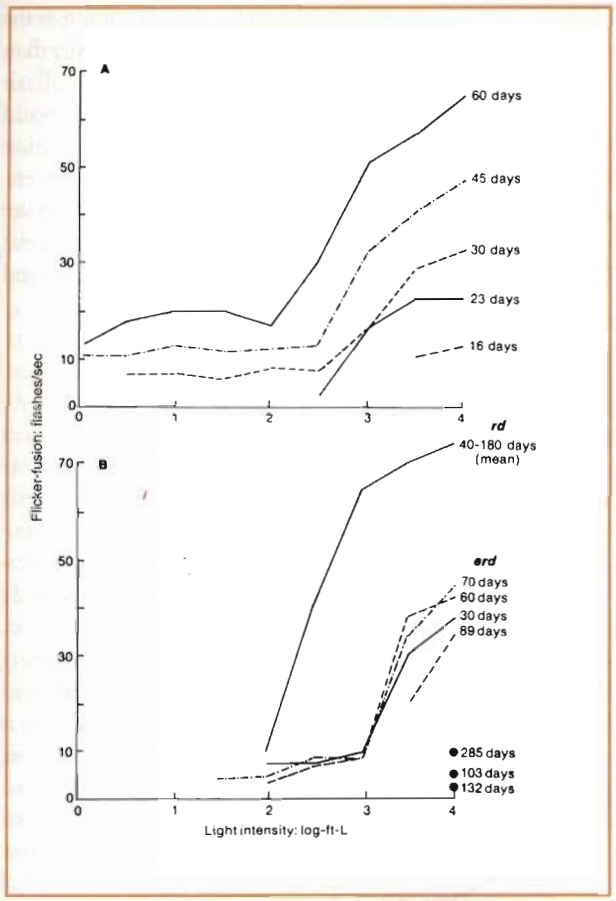

Figure 2—Flicker-fusion frequency (1 flash/sec = 1 Hz) as a function of light intensity of the stimulus (log-ft-L; units of luminance: 1 foot-lambert [ft-L] = 3.426 candelas/m² [cd/m²]) in the retinal development of *(A)* control dogs and *(B)* dogs with early retinal degeneration *(erd)*. The flicker-fusion frequency is defined as the frequency of the flickering light at which flickers are perceived to fuse into a constantly illuminated light. *(A)* In young dogs, flicker responses can be elicited by high-intensity stimuli only and the curve contains what is referred to as the *cone branch*. By 30 days of age, the curve is bipartite, with a rod branch at lower light intensities and an angle or break point between the rod and cone branches. With time, peak fusion frequencies increase at each intensity level and the break point shifts toward the left. *(B)* Dogs with erd have a bipartite curve, but the break point between the rod and cone branches is displaced toward the right on the intensity axis. The rod branch never matures and is lost by 89 days of age. The cone branch degenerates slowly, and responses in older affected animals (103 to 285 days of age) can only be recorded by using maximum light intensities. For comparison, flicker-fusion data for Norwegian elkhounds with rod dysplasia *(rd)* are included. In dogs with this disease, the rod branch cannot be recorded and the cone branch is normal. (From Acland GM, Aguirre GD: Retinal degeneration in the dog: IV. Early retinal degeneration [erd] in Norwegian elkhounds. *Exp Eye Res* 44(4):501, 1987. Reprinted with permission. Comparative data for rod dysplasia obtained from Aguirre GD: Retinal degeneration in the dog: I. Rod dysplasia. *Exp Eye Res* 26(3):233–253, 1978.)

TABLE I
Example of a Protocol for Electroretinographic Recordings[a]

Test	*Light Stimulus*	*Intensity of Stimulus per Flash (cd sec/m²)[b]*	*Test Conditions*
1	Single flash	3.0	Photopic
2	Single flash (dark adaptation of 5 min)[c]	0.03	Scotopic
3	10-Hz flicker (5 flashes and dark adaptation of 1 min)[c]	0.03	Scotopic
4	Single flash (dark adaptation of 1 min)[c]	0.3	Scotopic
5	20-Hz flicker (10 flashes and dark adaptation of 1 min)[c]	0.3	Scotopic
6	Single flash (dark adaptation of 1 min)[c]	3.0	Scotopic
7	50-Hz flicker (27 flashes and dark adaptation of 1 min)[c]	3.0	Scotopic

[a] The duration of an individual flash is 20 µsec for all the tests.
[b] cd sec/m² = candela seconds/m².
[c] The dark adaptation time described in parentheses is performed before the particular test that is listed.

ing is done after 5 minutes of adaptation to the dark environment (Table I). Tests 1, 6, and 7 primarily evaluate cone pathways; whereas the other steps evaluate rod pathways. Photopic conditions are followed for test 1 and scotopic conditions for tests 2 through 7 (Table I). Adaptation to a dark environment typically occurs in 20 to 30 minutes.[1] If the retina has been exposed to intense light, at least 1 hour is required before complete adaptation to the dark environment.[1]

Because the protocol at the UF-VMTH uses only sedation to restrain the patient, the procedure fits realistically into a hospital schedule. Adaptation to the dark occurs in 5 minutes, with 1-minute waiting periods between individual scotopic tests to maintain a dark-adapted state. This relatively short adaptation period is sufficient to determine basic functioning. If the patient is being tested for early, subtle stages of retinal degeneration, then general anesthesia and a 20-minute time frame for adaptation to the dark environment are required.

The UF-VMTH protocol also takes into account that rod responses require adaptation to the dark and relatively weak stimuli and therefore should be recorded before cone responses, which require brighter stimuli. After a protocol has been established, it should be followed for all electroretinographic recordings.

Oscillatory Potentials

Oscillatory potentials (OPs) cause a notching in the peak of the b-wave (Figure 3). By varying the filtering technique

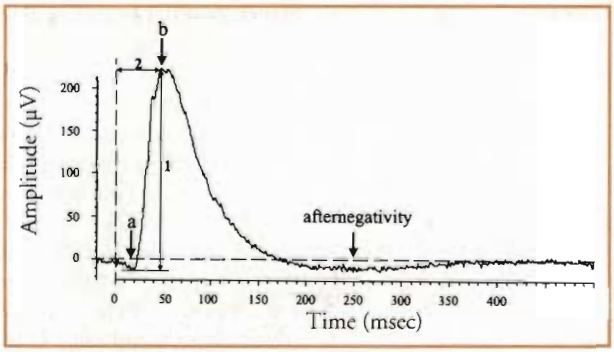

Figure 3—This normal flash electroretinogram of a cat shows the negative a-wave (*a*) and the positive b-wave (*b*) as well as the afternegativity. The positive c-wave is not visible on this recording. The amplitude (*1*) and implicit rime (*2*) of the b-wave are indicated. The b-wave amplitude is measured from the peak of the a-wave to the peak of the b-wave. The implicit time is the time from the light flash (0 msec) to the b-wave peak. Oscillatory potentials are responsible for the notching of the b-wave peak.

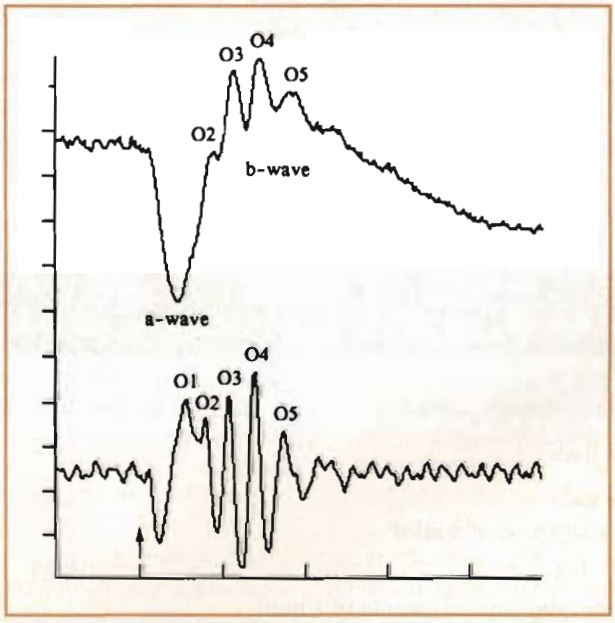

Figure 4—This electroretinogram (ERG) shows the oscillatory potentials (OPs) that were recorded for a dog (*top of figure*). Responses were initiated by a single white flash after 1 hour of adapration to a dark environment. Oscillatory potentials are labeled *O1* through *O5*, with O2 through O5 partially masking the b-wave. Raising the setting of the low-frequency filter higher than that recommended for ERGs virtually removes the ERG, leaving only the OPs (*bottom of figure*). *Arrow* = flash discharge; *horizontal division* = 25 msec; *vertical division* = 48.8 μV (*top*) and 9.76 μV (*bottom*). (From Sims MH, Brooks DE: Changes in oscillatory potentials in the canine electroretinogram during dark adaptation. *Am J Vet Res* 51(10):1581, 1990. Reprinted with permission.)

(i.e., adjusting the setting of the low-frequency filter higher than that recommended for flash ERGs) and introducing special stimulus and light-adaptation conditions, OPs can be enhanced (Figure 4).[3-5] They are believed to originate from the inner retina and are discussed later in this presentation.

Pattern Electroretinogram

In contrast to the flash ERG, which originates in the outer retina, a PERG directly reflects the functioning of retinal ganglion cells and therefore can be used to diagnose disorders of the inner retina, such as glaucoma.[6] A reversing pattern (e.g., a checkerboard or a series of grating stimuli) is projected onto the retina. The total quantity of light that enters the eye remains constant as the pattern reverses; however, in the region of the retinal image, repetitive changes in illumination occur.[6] The PERG response consists of at least three waves, with their amplitudes, implicit times, and areas under the curve of primary interest.[6] Limits to visual resolution can be estimated by a PERG. In dogs, the central retina is characterized by a higher degree of visual resolution than that of the more peripheral retina.[7] Pattern electroretinography is rarely used in veterinary ophthalmology because the procedure requires general anesthesia and the use of equipment that can refract each eye to ensure the image is focused on the retina.

Visual Evoked Potentials

Visual evoked potentials (VEPs), also called visual

evoked responses or visual evoked cortical potentials, reflect central visual function (i.e., the specific response of the visual cortex to different stimuli). The exact location of the cortical area of central vision has been reported for beagles and greyhounds (11.3 to 15.6 mm rostral to the interaural plane and 8.3 to 8.5 mm lateral to the median plane) and for cats (3 mm caudal to the interaural plane and 5 mm lateral to the median plane).[8,9] Although they are not ERGs, VEPs can be recorded with the same equipment by extracting electric signals from background noise or from electroencephalograms.[10] ERGs and VEPs are routinely analyzed in veterinary ophthalmology to differentiate between retinal, optic nerve, and cortical anomalies (which are discussed later). At the UF-VMTH, VEPs of a stimulated eye are recorded by placing the active electrode over the contralateral visual cortex of the brain and the reference electrode near the base of the contralateral ear. The ground electrode can be positioned at various locations (e.g., near the apex of the contralateral ear) as long as the same placement is consistently used for each recording. Thirty-two flashes at 1-second intervals with a duration of 20 µsec and an intensity of 3.0 cds/m^2 are used for stimulation; the 32 responses (between 100- and 500-msec long) are then averaged.[10] The remaining recording parameters, such as the filter settings, are similar to those used for flash ERGs.

NORMAL FLASH ELECTRORETINOGRAM

An ERG records the summation of the changes in membrane potentials in all the cells of the retina. For several decades, physiologists have attempted to relate specific components of ERGs to the activity of subsets of retinal cells. Initially most of the research involved lower vertebrates, and only with caution could results be extrapolated to mammals. The following discussion summarizes the current interpretation of an ERG for dogs and cats.

Four primary features of the ERG can be recognized (Figure 3): the a-wave (first negative peak); the b-wave (first positive peak); afternegativity, which follows the b-wave; and the c-wave (second positive peak), which is attenuated and distorted by most filters. The c-wave is usually not apparent under the conditions used in most veterinary laboratories because of its long implicit time.[1] Implicit time is the time from onset of the stimulus to the peak of a particular response.

The a-wave can be explained as the sum of photoreceptor and bipolar cell components, although major components of the inner retina (especially amacrine cells) also contribute.[11] Only the initial part of the a-wave specifically represents photoreceptor activity. After the response reaches little more than half of the negative peak value, the bipolar cell component becomes more apparent.[11] Early research suggested that the b-wave was generated by the response of Müller cells to extracellular changes in potassium levels secondary to the activity of ON-bipolar cells, which are bipolar cells activated by an increase in luminance.[12] More recent research has associated the b-wave directly with the extracellular flow of current produced by ON-bipolar cells.[13,14] Because blocking the response of Müller cells with barium ions does not eliminate the b-wave; ON-bipolar cells are believed to be the major contributor to the b-wave.[15–20] The shape of the b-wave, however, is also influenced by the activity of other cell types; the contribution of Müller cells to the b-wave therefore cannot be ruled out.[17] The c-wave correlates with polarization of pigment epithelium.[21–24]

Although OPs have been observed in humans since the 1950s, these potentials have not been described in dogs until recently.[4,5,25,26] In humans, researchers believe that OPs depend on the integrity of the retinal vasculature. Changes in the OPs are apparently the initial changes observed in patients with retinal disorders associated with retinal ischemia (e.g., diabetic retinopathy).[27] The OPs consist of five rapid, low-amplitude potentials, sometimes called wavelets, that are superimposed on the b-wave (Figures 3 and 4). Depolarizing amacrine cells (particularly those that produce sustained responses to light), bipolar cells, and depolarizing interplexiform cells are apparently the primary candidates for generating OPs.[28,29] Thus, OPs can be used as a selective probe of certain neural circuits in the inner retina.

FACTORS THAT INFLUENCE QUALITY

Controllable Factors

The type of wetting solution on the contact lens (wetting solutions must have ions), ambient temperature, intraocular pressure, retrobulbar injection of anesthetic, oxygenation and blood glucose levels of the animal, and electric and optic properties of the stimulating and recording systems can influence ERG results.[30] In addition, the intensity and wavelength of the stimulus, the flickering rate, and adaptation of the retina to light affect the results. Two additional factors that can cause variation in a flash ERG are pupil size and the depth and type of anesthesia. Maximum dilation of the pupil is required to ensure that the amount of light illuminating the retina is as high and constant as possible. In dogs and cats, maximum dilation usually occurs by applying topical 1% tropicamide. In addition, the light source can be flashed into an open white sphere that is positioned in front of the eye to ensure equal illumination of the entire retina. By using this full-field

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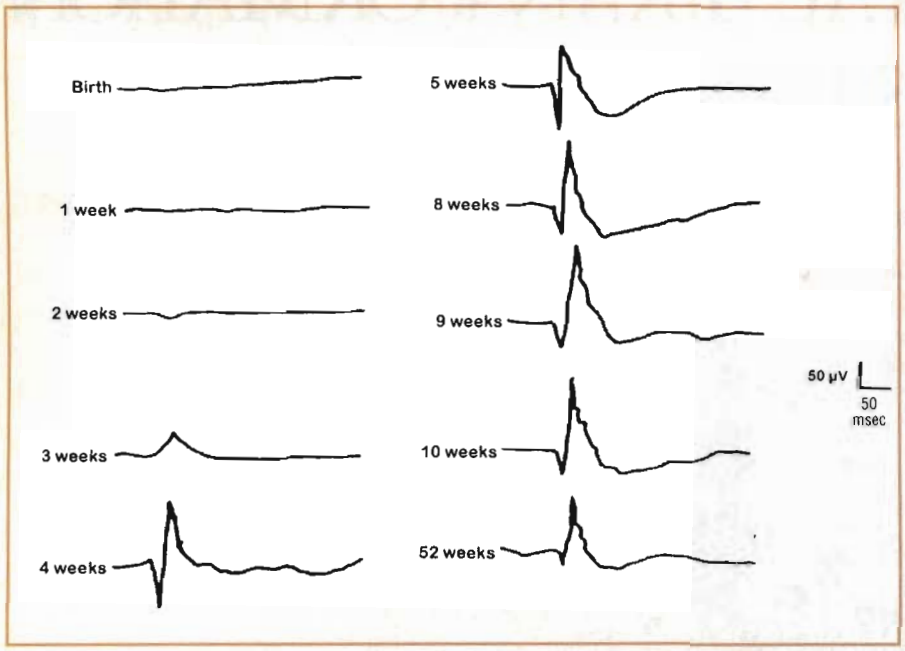

Figure 5—These electroretinographic recordings of beagles of different ages were taken after the dogs were exposed to 15 minutes of a dark environment. (From Gum GG, Gelatt KN, Samuelson DA: Maturation of the retina of the canine neonate as determined by electroretinography and histology. *Am J Vet Res* 45(6):1167, 1984. Reprinted with permission.)

(ganzfeld) stimulation, the problem of scattered light can be eliminated[31]; however, such stimulation is seldom used in veterinary electrophysiologic testing.

According to Acland, the recording of ERGs on unanesthetized animals cannot be successful because muscular movement (i.e., recording electromyograms) can influence the ERG recording, precisely controlled alignment of the light delivery system with the eye is required to obtain consistency, and the positions of the recording electrodes may be affected by patient movements.[1] Realistically, general anesthesia may be necessary. Halothane (a common anesthetic agent) can, however, influence the results of ERG recordings, although the effects are usually insufficient to interfere with interpretation.[32-34] Some authors failed to detect any effect of halothane on the ERG.[35-37] No studies have been performed to determine the effect of isoflurane, another common veterinary anesthetic, on the ERG. Regardless, the effects of any variation in technique, such as the anesthetic agent, must be evaluated before diagnostic electroretinography is initiated.

During the past 3 years, the ophthalmology service at the UF-VMTH has used intravenous acepromazine maleate (0.02 mg/kg) and butorphanol tartrate (0.2 mg/kg) to sedate dogs before beginning an ERG. Most dogs can be manipulated quite easily when sedated with this combination. Several hundred cases have been satisfactorily tested for diagnosis of sudden acquired retinal degeneration syndrome (SARDS) and presurgical assessment of retinal function before cataract removal. The use of sedation instead of general anesthesia saves time and expense. In addition, sedation is an alternative for patients that might ultimately fail the electrophysiologic examination. In the past, these patients were given general anesthetics even though surgery was never performed. Another advantage with sedation is that it can shorten the amount of time that surgical patients are eventually exposed to general anesthetics. Only in a small number of canine patients at UF-VMTH has deeper sedation or general anesthesia been required because of lack of cooperation or because early evaluation of PRA is required. In contrast, most cats do require general anesthesia. Intravenous ketamine hydrochloride (2 to 4 mg/kg) has been proven most valuable because the position of the globe remains centered. To our knowledge, no data have been published on the effect of ketamine on ERGs of feline patients.

Noncontrollable Factors

In puppies and kittens, an ERG can be recorded at 1 to 2 weeks of age (Figure 5).[38,39] At 8 weeks of age, the ERG resembles that of an adult (Figure 5).[38] The amplitude of the b-wave increases up to 9 weeks of age.[30,39] Whether the b-wave amplitude decreases or increases after 1 year of age, however, is controversial.[30] A decrease in ERG amplitudes would be expected because the number of photoreceptor and retinal pigment epithelium (RPE) cells decreases with age.[40] In dogs, such a decrease can reach 75% from about 60 days until 6 years of age.[41] Therefore, normal ERG values must be established for different age groups.[30] The specific ages of these groups are determined by a number of factors, such as the breed and the age when breed-specific retinal diseases most often occur. Figure 2 shows the developmental changes in the flicker-fusion curve in dogs during the first 60 days of life. In addition, researchers believe that breed-related differences also influence ERG amplitudes.[42] Therefore, a database of normal ERG amplitudes according to species, breed, and age

would be a useful reference for diagnostic ERGs in each hospital that performs electroretinography. Such a database, however, is not always practical because it requires a large and varied case load.

INTERPRETATION OF ELECTRORETINOGRAMS

The size of the b-wave amplitude (in μV) is most often used to interpret a clinical ERG because the b-wave is usually the largest wave with a distinct, easy-to-measure peak. Low b-wave amplitude indicates a decrease in the number of functional photoreceptors (e.g., as occurs in patients with PRA). Theoretically, the amplitudes of the a- and c-waves could also be used to interpret retinal function. The b-wave amplitude is measured from the peak of the negative a-wave to the peak of the positive b-wave (Figure 3). The implicit times of the three waves, especially the b-wave, are also used for interpretation (Figure 3). Any change in implicit time suggests abnormal function.[43] Finally, any shift of the flicker-fusion curve must be determined. Figure 2 shows the degeneration of the cone branch in patients affected by early retinal degeneration and the nonrecordable rod branch in Norwegian elkhounds with rod dysplasia.

TABLE II
Localizing Blinding Disorders Using Electrophysiologic Methods

	Location of Disorders			
Expected Changes	*Outer Retina*	*Inner Retina*	*Optic Nerve*	*Visual Cortex*
Flash ERG	X			
Pattern ERG	X	X	(X)[a]	
VEP	X	X	X	X

[a](X) = If the disease process progresses to retinal ganglion cell bodies, changes in pattern ERGs can be expected.
ERG = electroretinogram; *VEP* = visual evoked potential.

INDICATIONS FOR ELECTRORETINOGRAPHY

When retinal disease is suspected and other diagnostic methods fail to identify the retina as abnormal, electroretinography is indicated. Because results of ophthalmoscopic examinations do not reveal the degree of retinal function, ERGs may be recommended even when changes are detected with the ophthalmoscope. Some patients can be staged for certain retinal diseases based on ERGs, or the development of a disease process can be monitored with serial ERGs. The following discussion cites the most common indications for electroretinography in dogs and cats.

In patients with cataracts, surgical removal can improve vision only if the retina is functional. Because many breeds that are predisposed to develop cataracts may also have hereditary PRA, the condition of the retina should be evaluated before cataract surgery is performed. Usually, ophthalmoscopy is not feasible because the lens is opaque. Light reflection and absorption by the opaque lens, however, generally have little effect on the electric response of the retina.[44] Ocular ultrasonography is usually also performed to check for retinal detachment.[45] The most accurate method that evaluates retinal function is electroretinography. A majority of the clinical ERGs performed at the UF-VMTH are done on candidates for cataract surgery.

In every case of blindness, whether the eye (peripheral blindness), the optic nerve, or the brain (central blindness) is the source must be determined. Even if ophthalmic examination does not reveal any abnormalities, the blinding disease could be caused by a retinal disorder. An ERG can help to identify or rule out the potential sources of blindness. A hypothetical case scenario would be a dog with sudden blindness of a few days' duration and no clinical signs that could help pinpoint the problem. In this case, SARDS and optic neuritis must be ruled out. The amplitudes in the ERG are significantly decreased in the early stages of SARDS; recordable retinal activity eventually disappears because of a lack of photoreceptor function, even though the fundus often appears normal for several weeks.[46,47] In patients with optic neuritis or cortical blindness, the ERG will probably be normal. Therefore, an additional electrodiagnostic test (i.e., the

recording of VEPs) may also be performed by the ophthalmologist (Table II).

Retinal degeneration is divided into cases that affect the photoreceptor layer (e.g., dysplasia or degeneration) and cases that involve the RPE. The former are often called PRAs, and the latter are termed RPE dystrophies or central PRAs. Electroretinography helps to confirm suspected retinal degeneration, especially in early stages when ophthalmoscopic abnormalities are not apparent. Signs of PRA on an ERG include decreased b-wave amplitude, decreased flicker-fusion frequency, and (less often) changed implicit times.[41–43] In several canine breeds (e.g., Irish setter and poodle), retinal degeneration or dysplasia is known or believed to be inherited.[48] Other causes of retinal degeneration are taurine deficiency in cats and degeneration from inflammation of the retina, the choroid, or both in cats and dogs.[49,50]

Glaucoma is a very complex disease of the rerina and optic nerve head. In patients with glaucoma, elevated intraocular pressure is the primary risk factor. The retina atrophies diffusely because of ischemia and pressure necrosis. Because the ganglion cells are damaged first, the results of a flash ERG are normal during the initial stages of the disease.[51] Only in later stages, when the outer retinal cells are also damaged, can abnormalities in the results of a flash ERG be detected. Pattern electroretinography is considered a useful tool for quantitative assessment of the damage to ganglion cells in the retina.[52,53] Therefore, pattern electroretinography is helpful in diagnosing the early stages of glaucoma. Initial attempts to use pattern electroretinography in dogs have failed to detect a substantial difference between the visual acuity of dogs with normal eyes and dogs with glaucoma.[7] Dogs with glaucoma, however, do respond differently in PERGs of the peripheral retina after injection of thiamylal.[54,55]

SUMMARY

An ERG, which records changes of electric membrane potentials in the entire retina as a function of time, consists of a-, b-, and c-waves. The initial slope of the a-wave primarily represents photoreceptor cell activity, the b-wave the activity of cells in the middle retina, and the c-wave the activity of pigment epithelial cells. The rod and cone pathways are separately evaluated by subjecting the retina to different stages of light adaptation, different intensities of light flashes, and different light flash-flicker rates. The recording of an ERG is indicated when retinal dysfunction must be confirmed or ruled out, which most often is required during presurgical evaluation of patients with cataracts or for evaluation or diagnosis of disorders that lead to blindness, including retinal degeneration.

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ARTICLE #7 CE TEST

The article you have read qualifies for 1.5 contact hours of Continuing Education Credit from the Auburn University College of Veterinary Medicine. *Choose only the one best answer* to each of the following questions; then mark your answers on the test form inserted in *Compendium.*

1. A reference database with normal electroretinographic measurements should include the
   a. type of stimulating and recording systems used.
   b. age of the animal.
   c. animal species and breed.
   d. all of the above

2. Which of the following factors apparently affects flash ERGs the least?
   a. pupil size
   b. halothane
   c. age of young dogs (younger than 3 months of age)
   d. consistency of the stimulating system

3. Which of the following statements represents the primary reason the b-wave of a single-flash ERG is used most often to assess retinal function in dogs and cats?
   a. The b-wave primarily consists of photoreceptor components.
   b. Only changes in the implicit time and amplitude of the b-wave are noticeable in patients with such retinal diseases as PRA.
   c. The primary reason is convenience because the b-wave is the largest wave with a distinct, easy-to-measure peak.
   d. The a- and c-waves are harder to reproduce properly if the ERGs are repeatedly recorded for a period of time.

4. Which of the following statements about flash electroretinography is least applicable?
   a. Averaging several individual recordings is the only practical method to reduce the level of electric noise.
   b. A corneal contact lens electrode is often used as the active electrode to record ERGs.
   c. The stimulating and recording systems are the two primary components of an electroretinographic unit.
   d. The typical bandpass that is used for differential amplifiers is from 1 to 300 Hz.

5. In patients with glaucoma, the functioning of retinal ganglion cells can be evaluated most specifically by recording
   a. flash ERGs.
   b. OPs.
   c. PERGs.
   d. VEPs.

6. To detect early stages of retinal degeneration in a dog placed in scotopic conditions, the animals must adapt to the dark environment for how many minutes?
   a. 20 to 30
   b. 10
   c. 5
   d. 2 to 3

7. Which of the following lists of clinical findings accurately indicate degeneration of rod photoreceptor cells?
   a. bumping into objects during daylight, decreased photopic b-wave amplitude, and decreased flicker-fusion frequency at high-intensity light
   b. bumping into objects during daylight, decreased photopic b-wave amplitude, and decreased flicker-fusion frequency at low-intensity light
   c. bumping into objects during daylight, decreased scotopic b-wave amplitude, and decreased flicker-fusion frequency at low-intensity light
   d. bumping into objects at low levels of light, de-

(continues on page 399)

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Electroretinography. Part II *(continued from page 366)*

creased scotopic b-wave amplitude, and decreased flicker-fusion frequency at low-intensity light

8. The b-wave of flash ERGs is believed to be primarily generated by _____ cells.
   a. photoreceptor
   b. Müller
   c. ON-bipolar
   d. amacrine
   e. RPE

9. In which of the following disorders are retinal ganglion cells primary affected?
   a. central PRA
   b. PRA
   c. retinal detachment
   d. glaucoma

10. A patient with acute bilateral blindness caused by opic neuritis has a(n)
   a. normal flash ERG and normal VEPs.
   b. normal flash ERG and abnormal VEPs.
   c. abnormal flash ERG and abnormal VEPs.
   d. abnormal flash ERG and normal VEPs.